THE EFFECTS OF CHOP QUALITY, COOKING METHOD, AND DEGREE OF DONENESS ON CONSUMER ACCEPTABILITY OF BONELESS PORK CHOPS

BY

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THESIS

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ABSTRACT

Pork production practices such as genetics and nutrition have continued to change due to increased local and global demand for pork, as well as a contrast in international consumer expectations of pork quality. While many of these changes occur on the live pig, it is necessary to ensure that such changes are not having adverse effects on the overall quality of products. Consumers make the final estimation of quality therefore, adverse effects on pork quality may translate into a poor eating experience, ultimately decreasing consumer purchase intent. Pork sensory quality (tenderness, juiciness, and flavor) is influenced by several factors that can occur before, during, and after the harvest process. For the following experiments, influencing factors were comprised of chop visual quality (visual color and marbling), ultimate pH of the chops, cooking method, and degree of doneness. These influencing factors were evaluated to determine their impact on consumer acceptability of boneless pork loin chops.

Consumers (396 total) were served chops in 1 of 3 experiments. Chops in experiment 1 were classified as either “choice” or “standard”. Chops classified as “choice” had a NPPC visual color score ≥ 3 and a visual marbling score ≥ 2. Chops were classified as “standard” when NPPC scores did not meet the qualifications for “choice”. Chops in experiment 1 were then cooked to either 63°C or 71°C. Chops in experiment 2 were categorized as high pH (5.88-6.23) or low pH (5.36-5.56) and cooked to 63°C, 71°C or 82°C. Chops for experiment 1 and 2 were cooked with an immersion cooker sous-vide device. Chops in experiment 3 were cooked to either 63°C or 71°C using either an open-hearth grill or an immersion cooker sous-vide device. During experiments 1 and 2, consumers were seated in a sensory room under red light to mask color differences. During experiment 3, consumers were served samples under white light to allow for cooked color appraisal. Consumers in all three experiments used a 9-point Likert-type score

system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were consider neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Data were organized as a percentage of responses and analyzed using the GLIMMIX procedure of SAS for all three experiments. Additionally, a pre- and post-survey were given in experiment 3 to determine if consumer's perceptions of degree of doneness changed after completing the sensory panel.

Quality grade did not affect ($P \geq 0.30$) consumer ratings for any sensory trait. More ($P < 0.01$) consumers rated chops with a high pH (36.07%) as juicy compared with low pH chops (24.29%), but pH category did not alter ($P \geq 0.13$) perceptions for tenderness, flavor, or overall acceptability. In experiments 1 and 2, a greater ($P < 0.001$) percentage of consumers rated chops cooked to 63°C as acceptable compared with chops cooked to 71°C. Within experiment 3, there was an interaction between cooking method and degree of doneness for both tenderness and acceptability. Consumers rated a greater percentage ($P < 0.001$) of chops cooked sous-vide at 63°C as tender (82.82%) and acceptable (60.34%) compared with all other cooking method/degree of doneness combinations. There were no differences ($P = 0.06$) in the percentage of chops rated tender when chops were cooked to 71°C using either sous-vide (33.07%) or grilled (22.42%) cooking methods. Additionally, there were no differences ($P = 0.06$) in the percentage of chops rated acceptable when cooked to 71°C using either sous-vide (26.35%) or grilled (28.63%) cooking methods. For juiciness, consumers rated a greater ($P < 0.01$) percentage of chops cooked to 63°C juicy (44.37%) than those cooked to 71°C (14.78%) but ratings did not differ between cooking methods. For flavor, consumers rated a greater ($P < 0.01$) percentage of chops cooked to 63°C as flavorful (34.61%) than those cooked to 71°C (24.31%).

Contrary to our hypothesis, ratings as flavorful did not differ between cooking methods (P = 0.88). Even when consumers could identify cooked color, they preferred chops cooked to 63°C, and the lack of browning on chops cooked sous-vide did not compromise the eating quality. Survey results indicated that consumers acknowledged that pork could safely be cooked at a lower temperature and preferred a pork chop cooked to a lower degree of doneness after participating in the sensory panels. Overall, it was degree of doneness that had a greater impact on consumer eating experience than “quality grade” or ultimate pH.

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CHAPTER 1

REVIEW OF THE LITERATURE

Introduction

According to the Pork Checkoff, pork is the number one consumed meat animal protein in the world (Pork Checkoff, 2018). Currently, 52% of global pork production is produced in an indoor setting (de Haan et al., 2006). In the United States, over 99% of market pigs are raised indoors (NAHMS, 2012a). Over the past decade, the pork industry has shifted from outdoor production to a confinement setting (NAHMS, 2012b). Utilizing indoor production, farmers have greater control over the environment, temperature, air flow, and exposure to disease. Because of indoor pork production, this helps to eliminate the risk of contaminations via *Trichinella sprilis*, allowing for pork to be safely consumed at lower internal cooking temperatures (Pyburn et al., 2005). Genetic improvement has also attributed to more efficient production of pigs with better feed to weight gain conversion. Finishing pig diets have not deviated much from a corn and soybean based diet, but additional alternative feed sources have a positive contribution to pork production. Nutritional requirements of growing-finishing pigs have not changed, but energy sources have become more expensive. So, alternative energy sources are sought which increases the need to monitor fat quality. With improvements and changes in production practices, genetics, and nutrition, the meat industry works to ensure improvements made on the live pig still provide positive improvements to the pork products that are produced. If the pork we are producing is not desirable by consumers, changes need to be made to meet the consumers' needs and demands, as the consumer makes the final estimation of quality for all meat products. Consumers perception of the meat industry is important and helps to guide the type of research that meat scientist need to focus on. Making pork tender, juicy, and flavorful is influenced by several quality factors that can occur before, during, and after the harvest process.

Therefore, the objective of this literature review is to discuss what pork quality traits can influence tenderness, juiciness, and flavor of pork, how to measure tenderness, juiciness, and flavor of pork, and how consumer relate tenderness, juiciness, and flavor of pork. Next, implementing a proposed pork quality grading system will be discussed. Then, how final internal cooking temperature can effect sensory traits and what impact pork color and cooked color have on consumers will be analyzed. Cooking methods of consumers and researchers will be touched. Finally, some closing remarks and discussion of studies.

Tenderness

Tenderness is impacted by several factors including rate of tenderization during aging, and muscle contraction during the onset of rigor (Lawrie, 2017). Moeller et al. 2010 reported by increasing pH by 0.20 units, tenderness-like was also increased 0.20 units. The pH of muscle is defined as the amount of hydrogen ion concentration within the muscle. Normal muscle pH is approximately 7.2 and then after 24 h post mortem the ultimate pH decreases to around 5.60 (Lawrie, 2017). The amount of glycogen pre-slaughter will determine the amount of lactic acid that will accumulate during the conversion of muscle to meat causing the pH of the meat to drop (Huff-Lonergan et al., 2002; Lonergan, 2012). Once an animal is exsanguinated, the blood is gone and no longer carrying oxygen or heat throughout the animal's body. During the citric acid cycle, lactate acid is made and carried away by the blood. Without the blood present, lactic acid builds up causing the decrease of muscle pH. The rate of pH decline has an effect on the quality of the meat. A rapid pH decline but similar end point pH as normal meat would be considered pale, soft, and executive (PSE) meat. A greater than normal ultimate pH will result in dark firm and dry or DFD meat. Chops that appear darker in color tend to have a greater ultimate pH, and chops with a lighter color will have a lower ultimate pH (Monin and Sellier, 1985). When pigs are stressed right before slaughter, they have a greater glycogen build up which when converts to lactic acid causes a rapid drop in pH. Additionally, lipids can have a positive effect on tenderness as the fat cells within the perimysium physically separate muscle fiber bundles, thus opening up muscle structures and weakening the connective tissue. (Wood et al., 2003; Lawrie, 2017). During post mortem ageing of meat, myofibrillar and sarcoplasmic protein in the meat start to degrade. This degrading of proteins causes the muscle structure to change, therefore altering meat tenderness (Wagner, 2007).

Tenderness of meat can be analyzed objectively by instrumental measures. Two of the most common ways to measure instrumental tenderness is to use sliced shear force or Warner Bratzler shear force. Typically, slice shear force is used when evaluating beef cuts (AMSA, 2015). For one steak, a 1 cm thick 5 cm long samples is cut parallel to the muscle fibers using a knife and samples sizing box at a 45° angle. The sample will be placed into the test machine with a shear blade that will cut perpendicular to the muscle fibers. Warner Bratzler shear force uses a similar machine with a v shaped blade to slice through cored samples (AMSA, 2015). One end of the chop is sliced to expose the muscle fibers orientation. This orientation of fibers is used when coring out samples to ensure that muscle fibers are running parallel to the corer. Choosing cores that are uniform in diameter is important to obtain a correct shear force value. A total of five cores are sheared perpendicular to the muscle fibers. The force required to break through the fiber is measured in kilograms of force. Therefore, a lower value indicates a more tender sample (AMSA, 2015). A samples is considered tender when the WBSF value is below 4 kg (Wheeler et al., 1997). Moller et al. 2010 reported that for every .541kg increase in WBSF, sensory tenderness scores decrease by 0.37 units. Trained or consumer sensory panels are a subjective way to determine pork tenderness. Typically, trained panelist go through multiple trainings to become calibrated to anchors that are used for trained sensory panels. For tenderness calibration, muscles that are typically different in tenderness are used as anchors. A strip loin steak is an intermediate or a mid-point anchor on the scale. A steak from an older cow would be a tougher samples for a tough anchor. Then finally a tenderloin steak would be the anchor for the tender side of the scale. When consumers are used for sensory test, no pre training is given. Consumers are given samples and asked to rate or rank samples based on the tenderness. Consumers can come in with pre-established ideas of what they consider tender and not. Although consumers are not trained or calibrated, consumers are the ones who are purchasing and preparing the pork products. Consumers use sensory traits like tenderness to determine how satisfying the overall product is and if they will purchase pork again (Grunert et al. 2004).

Juiciness

Water makes up about 75% of muscle tissue (Lawrie, 2017). In meat, water can be bound at three different states to myofibrillar proteins. Bound water is tightly bonded to proteins and is not easily freed. Immobilized water makes up the greatest percentage of water within the muscle. Free water can be easily lost with the cutting of the meat. Myofibrillar proteins that bind to water can denature when a rapid pH decline occurs. This denaturing of protein causes water that was once bound to then be loss and resulting in PSE meat. Water holding capacity (WHC) is decreased and purge loss will be increased in PSE meat. Lipids can also trap water within the muscle causing an increase in juiciness (Wood et al. 2003)

Huff-Lonergan et al. (2002) reported significant ($P < 0.001$), but weak correlations between both drip loss % (r= -0.33) and cook loss % (r= -0.20) to ultimate pH. This indicated that ultimate pH can have an effect on the water holding capacity of meat. Additionally, cook loss was moderately (r= -0.54) correlated to sensory juiciness scores (Lonergan et al., 2007) Cooking method can have an effect on juiciness scores. Prestart et al. (2002) reported an increase of 15.67 units for juiciness scores on a 150mm scale of chops that were grilled compared to chops fried. To measure juiciness objectively, using a cook loss percentage would be a good indicator of how much moisture was lost during the cooking process. To measure cook loss, take the initial weight of the chop prior to cooking to have a starting weight. Then after a chop is cooked using the desired cooking method, the chop is allowed to cool, then a cooked weight is recorded. The following equation is used to determine cook loss percentage:

$$\textit{Cook loss (\%)} = \{[\textit{Initial wt (g)} - \textit{Cooked wt (g)}] / \textit{Initial wt (g)}\} \times 100$$

A subjective method to measure juiciness is to use trained or consumer sensory panelists. Once again, a trained panelist has to go through specific training in order to be calibrated properly. According to the AMSA guidelines, strip loin steaks are cooked to a high final internal temperature and pressed before serving in order to anchor panelists to a very dry sample. Strip loin steaks are cooked to 70℃ and served as a standard or middle of the road sample for juiciness. Finally, strip loin steaks are cooked to 60℃ and served as a sample that is higher than previous samples for juiciness. Consumer panelist can be used once again for sensory panels, however consumers are not trained to detect differences. Evaluation sheets should be simple and ask if the sample is dry or juicy with those parameters as anchors. In addition to tenderness, consumers use juiciness of pork for overall satisfaction and intent to repeat purchase of the product (Grunert et al. 2004).

Flavor

Raw meat does not have a specific aroma but meat develops flavor as it cooks (Lawrie, 2017). Cooked meat flavor is a product of the Maillard reaction which is a reaction between amino acids and reducing sugars (Baldwin, 2012). During the cooking of meat the fatty acids within the meat produces volatile and lipid oxidation products giving meat an odor and flavor (Wood et al., 2003). Pigs fed a diet including linseed had low flavor scores and higher abnormal flavor scores by trained sensory panels (Wood et al., 2003). Trained sensory panelists indicated an increase in off flavor of hams fed a diet including canola oil (Shackleford et al., 1990). Additionally, intact male pigs have high levels of androstenone and skatole in the fat given the meat a boar taint smell and taste (Babol and Squires, 1995).

Moeller et al. 2010 reported an improved flavor like by 0.10 units by increasing pH by 0.20 units. Additionally, as the intramuscular fat percentage increases, trained sensory panel scores were predicted to increase for both fat flavor level and lean flavor level (Moeller et al., 2010). Perirernal or visual fat, subcutaneous fat (underneath the skin), intermuscular (seam fat), and intramuscular fat (marbling) are adipose tissues that can be deposited in different anatomical locations of a pig. Intramuscular fat or marbling is one of the visual cues that consumers use in purchasing decisions (Brewer and McKeith, 1999). National Pork Board benchmark retail audit of 2013 indicated 45% of non-enhanced center-cut pork loin chops had a visual marbling score of 2 (Klinkner 2013). The National Pork Board Visual marbling scores are intended to represent the percentage of lipid in a pork chop. As an example, a chop with a visual marbling score of 2 should have 2% of extractible lipid. Extractable lipid is an objective measurement of intramuscular fat. Huff-Lonergan et al, (2002) reported a moderate (r=0.57) correlation between % lipid and marbling score.

Instrument measurements such as an electronic nose-can be used to detect differences in volatiles and predicted spoilage. Also an electronic tongue can also detect differences in salt levels in a sample (Baldwin, 2011). According to one study, structural lipids of cooked pork make up a large source of flavor volatiles that are detected by a gas chromatography (Mottram et al., 1982). Flavor can also be subjectively measured by trained and consumer sensory panelist (AMSA, 2015). Trained panelist can go through intense training to detect different types of flavor and aromas similar to that of the various types of flavors and aromas that the machines can pick up. However, because pork flavor is typically not as complex as a beef flavor profile, trained panelists just identify the pork flavor or intensity of pork flavor. Consumer panels on the other hand are a little harder to use for pork flavor. Because there is no training and pork samples served to consumers normally does not have any seasoning on it, pork flavor can be skewed to a lower flavorful score compared to maybe beef.

Quality Grading System

Consumer's acceptability of a grading system was assessed by a report prepared for the National Pork Board (Lusk et al., 2016). Summarizing the survey results were that a grading system similar to that of the beef industry would increase a consumer's intention to purchase pork. However 20-30% of consumers who were presented with pork using a grading system still choose to purchase the lower quality chops. Sixty percent of participants indicated that pork color and the store where the pork was purchase were indicator of flavor juiciness and tenderness. Using marbling to assess those sensory traits were only used by a third of the participants.

Consumers use visual color and marbling as indicators of tenderness and juiciness (Wood et al., 2004; Lonergan et al., 2007). In 2017, the United State Department of Agriculture proposed a quality grading system to stake holders of the pork industry for comments (USDA, 2017). This proposed grading system used NPPC visual color and marbling as criteria where darker chops with greater marbling grade higher than lighter chops with less marbling (Table 1). In one study (Wright et al., 2005), trained panelists were unable to detect sensory tenderness differences among high, average, and low quality grade chops cooked to 70℃. High quality chops had either a NPPC color score of >3 or NPPC marbling score of >4. Low quality chops had either a NPPC color score or NPPC marbling score of 1. Average quality chops were chops that had NPPC color and marbling scores in between high and low quality. However, high quality chops were instrumentally more tender than low quality chops cooked to 70℃. Trained panelists were able to detect differences in sensory juiciness where high quality chops were more juicy compared to average and low quality chops cooked 70℃. Wilson et al. (2017) evaluated the effect of instrumental color and extractable lipid content on sensory characteristics of pork chops cooked to 63℃ by trained sensory panelists. This study concluded that extractable lipid was not predictive of any sensory traits and instrument color was only weakly (1%) predictive of sensory tenderness. In conjunction, Klehm et al. (2018) also reported no tenderness, juiciness, or flavor scores differences among different quality graded chops cooked to 63℃ using trained panelist. However, limited data is available as to how selecting chops using a grading system will affect consumers' sensory traits.

Final Cooking Temperature

In 2013, the USDA lowered the recommended final internal cooking temperature of whole pork muscles from 71℃ to 63℃ (FSIS, 2013). Lowering the cooking temperature of pork chops increased tenderness scores 4.6% and juiciness scores 10.1% by a trained sensory panelist (Klehm et al., 2018). Additionally, chops cooked to 63℃ were about 7% more instrumentally tender than chops cooked to 71℃ (Rinker et al., 2008). Rinker et al. (2008) reported decreased trained sensory tenderness scores (8.56 to 6.81) and juiciness scores (9.85 to 6.29) as internal cooking temperature increased from 62℃ to 80℃. Trained sensory panelist rated chops using 15-cm line scale where 0 is extremely tough/dry and 15 is extremely tender/juicy. Moller et al. (2010) reported increased tenderness (2%) and juiciness (12%) scores when chops were cooked to a lesser degree of doneness and rated by trained sensory panelist. As previously mentioned, Wilson et al. (2017) was one of the first studies to reevaluate visual color and visual marbling effects on pork chops cooked to a lesser degree of doneness. This study reported that independently, color and marbling only account for 2% of variation for any sensory trait using trained panelists when chops are cooked to 63℃. Richardson et al. 2018 reported that only when ultimate pH of pork chops was about 5.95 were chops more tender than any other pH categories when cooked to 63℃. Additionally, trained sensory panelists could not detect tenderness differences among various pH categories unless the pH was above 5.95 (Richardson et al., 2018). Limited data is available studying the effects of pork quality on consumer sensory traits when chops are cooked to the revised cooking temperature.

Typically red filtered lighting is used for sensory evaluate of pork to minimize any visual effects that a degree of doneness can have on acceptability (Miller, 2006). Visual color of cooked pork chops will become less pink as internal cooking temperature increase (Lien et al., 2002) For pork having a negative association with cooked color being indicative of safety, sensory panels are done under red lighting (Moller et al., 2010, Wilson et al., 2018, Klehm et al., 2018). A focus group conducted in 1998 indicated that consumers do not regularly use a meat thermometer when cooking. The focus group indicated that other methods such as cooking until no red/pink is inside or fluids run clear are used more frequently than a meat thermometer (FSIS, 1998). The United States Food and Drug Administration (FDA) food safety survey of 2016 indicated 67% of participants own a meat thermometer, however only 38% of those who own one use it for large pieces of meat and 10% use it for hamburgers (FDA, 2016). Although consumers have access to a meat thermometer, they are not using it consistently. With historical fear of cooking pork to a lower degree of doneness, when faced with a hot pink center of a pork chop, how would consumers react? If consumers are not regularly using a meat thermometer, they could be over cooking the pork product resulting in a negative eating experience.

Pork Color

Consumers use visual color when purchasing meat and tend to prefer reddish-pink lean pork (Brewer and McKeith, 1999). Additionally, one study indicated that consumers given the opportunity to visually appraise the chop before preparing it at home had higher liking tenderness and juiciness for darker colored loins of a NPPC color of 5 and 6 compared to paler color chops (Norman et al., 2003). A retail audit conducted in 2013 assessed non-enhanced pork chops (Klinkner, 2013). Trained personal use NPPC color and marbling cards to assess center-cut pork loin chops to assign color and marbling scores. The National Pork Board and National Pork Producers council established visual color and marbling scores (NPPC, 1999) to aid in visual appraisal of meat color and marbling. Other countries such as Japan and Australia have developed their own scoring system and cards. NPPC visual color scores are 1 to 6 with 1 being extremely pale and 6 being extremely dark. The majority (48%) of non-enhanced chops were rated a visual color score of 3, which is described as reddish pink color. Only 19% of non-enhanced chops were described as grayish pink as indicated by a color score of 2, while 26% of non-enhanced chops received a color score of 4 which is described as dark reddish pink. Variation within a retail case can lead to confusion on which chop will provide the best eating experience for a consumer. In 2016, an assessment of a proposed quality grading system reported 25% of participants indicated paler color chops would taste better (Lusk et al., 2016). Instrumental color score measurements can be an objective measurement to complement visual color scores. Pork color can be evaluated objectively by instruments such as a colorimeter or photo spectrometer using the Commission Internationale de l'Eclairage (CIE) record in L*, a*, and b* units (CIE, 1978). Lightness, or L*, is a measure of black (0) to white (100). Redness, or a*, is the measure of green (-60) to red (+60). Yellowness, or b*, is the measure of blue (-60) to yellow (+60) (AMSA, 2012). Subjective color and instrumental L* have a correlation (-0.69) which is consider relatively high given the threshold for high correlation is 0.68. Instrumental L* are predictive of subjective color scores (Huff-Lonergan et al., 2002). However, no instrumental or visual color parameters were moderately ($|r|= 0.36$ to 0.67) or strongly correlated ($|r|\geq 0.68$) with instrumental tenderness for chops cooked to a range of 63°C to 71°C as described in Harsh et al. (2018).

Cooking Methods

Generally, researchers prefer to use a broiling method to best replicate the most common way that consumers will prepare meat (AMSA, 2015). In a FDA survey, 52.3% of participants used a grill/barbecue when preparing pork chops, followed by sauté and roasting (48.7% and 34.5%, respectively) (FDA, 2016). Roasting is described in the American Meat Science Association sensory and tenderness evaluation guidelines, however it is not recommended for research because it does not meet the criteria necessary to produce consistent and repeatable data. Sous-vide is a common cooking method used within the restaurant industry. This cooking method allows for chefs to hold meat at a constant temperature over a long period of time without the meat going above the desired temperature. Most commonly, chefs will cook using the sous-vide method then sear both sides of the meat to create a Maillard reaction (Baldwin, 2012; Ruiz-Carrascal et al., 2019). Cooked meat flavor is a product of the Maillard reaction, which is a reaction between amino acids and reducing sugars (Baldwin, 2012). Currently, there is limited data on the effect that sous-vide alone (no searing) has on the sensory traits of pork chops served to consumers.

Conclusion

From this review, a few questions arise from the gaps within the literature. Within the last 8 years, FSIS has changed the recommended cooking temperature of whole muscle pork products. With the revised temperature, what pork quality measurements that have been historically used to predict eating experience are now relevant? With a proposed quality grading system, does color and marbling matter when you cook pork to a lower degree of doneness? Does ultimate pH still matter with the revised cooking temperature? With supporting data from trained sensory panelist, those traits may no longer be applicable at the lower degree of doneness. Limited data is available utilizing consumers as sensory panelist. If consumers were given the change to visually evaluate pork cooked to the correct temperature, what would they think? Therefore, the following chapters are experiments designed to address these questions. The first chapter is a study divided into two experiments. Experiment one addresses the effect of ultimate pH categories on consumer acceptability of pork loin chops cooked to three different degrees of doneness. The following experiment addresses the effect of a proposed quality grading system utilizing visual color and visual marbling scores on consumer acceptability of pork loin chops cooked to two different degrees of doneness. Chapter 3 address the effect of cooking method and degree of doneness on consumer acceptability of pork loin chops when consumers are allowed to visual apprise cooked color.

Table

Quality grade	Lean color score	Lean marbling score
USDA Prime	4-5	≥4
USDA Choice	3	≥2
USDA Select	2	≥2

Table 1.1: Proposed USDA pork quality grading system based on loin color and marbling[1]

[1]Adapted from USDA 2017

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CHAPTER 2

FINAL INTERNAL COOKING TEMPERATURE OF PORK CHOPS INFLUENCED CONSUMER EATING EXPERIENCE MORE THAN VISUAL COLOR AND MARBLING OR ULTIMATE PH

Abstract

The objective was to determine the effect of "quality grade" (combination of visual color and marbling) or ultimate pH on consumer eating experience of pork chops cooked to different final internal temperatures. The hypothesis was that consumers would rate a greater percentage of pork chops as acceptable when graded "choice", had a greater ultimate pH, or when cooked to 63°C compared with chops graded "standard", had a lesser ultimate pH, or when cooked to 71°C or 82°C. Consumers (264 total) were served chops in 1 of 2 experiments. Chops in experiment 1 were classified as "choice" when NPPC visual color score ≥ 3 and visual marbling score was ≥ 2 or "standard" when NPPC scores did not meet the qualifications for "choice" and were cooked to either 63°C or 71°C. Chops in experiment 2 were categorized as high pH (5.88-6.23) or low pH (5.36-5.56) and cooked to 63°C, 71°C or 82°C. Chops were cooked with a sous-vide device (ANOVA Precision Cooker, Anova Applied Electronics, San Francisco, CA) in a water bath. Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were consider neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Data were organized as a percentage of responses and analyzed using the GLIMMIX procedure of SAS for both experiments with models including treatment (quality grade, ultimate pH, and final internal temperature) and all interactions. Quality grade did not affect ($P \geq 0.30$) consumer ratings for any sensory trait. More ($P < 0.01$) consumers rated chops with a high pH (36.07%) as juicy compared with chops with a low pH (24.29%), but pH category did not alter ($P \geq 0.13$) perceptions for tenderness, flavor, or overall

acceptability. In both studies, a greater ($P < 0.001$) percentage of consumers rated chops cooked to 63°C as acceptable compared with chops cooked to 71°C. Therefore, internal cooking temperature has a greater impact on consumer eating experience than “quality grade” or ultimate pH.

Introduction

Consumers use visual color and marbling (intramuscular fat) as indicators of tenderness and juiciness when evaluating pork products for purchase (Wood et al., 2004; Lonergan et al., 2007). Because consumers value color and marbling when making purchasing decisions, The United States Department of Agriculture (USDA) used NPPC visual color and marbling as criteria for a proposed quality grading system where darker chops with greater marbling were valued over lighter chops with less marbling (USDA, 2017). Further, it has long been accepted that lighter colored chops have a lesser ultimate pH and darker colored chops have a greater ultimate pH (Monin and Sellier, 1985). Ultimate pH of pork chops was positively correlated with visual color and sensory tenderness (Huff-Lonergan et al., 2002). Additionally, increasing ultimate pH of fresh pork chops cooked to 71 °C increased sensory tenderness and juiciness (Lonergan et al., 2007) and cooking chops to 63 °C increased sensory tenderness scores (Richardson et al., 2018). Rincker et al. (2008) reported an improvement in sensory tenderness of pork chops cooked to 62 °C compared with chops cooked to 71°C or 80°C. Because of this, and because safety is not compromised, the USDA reduced the recommended endpoint temperature of pork muscle cuts, in 2011, from 71°C to 63°C as a means of improving sensory traits and maintaining food safety. However, there are limited data on the effects of ultimate pH or the proposed quality grading system on consumer acceptability of pork chops cooked to the revised internal cooking temperature recommendations. Therefore, the objective was to determine the effect of “quality grade” (combination of visual color and marbling) or ultimate pH on consumer eating experience of pork chops cooked to different final internal temperatures. The hypothesis was that consumers would rate a greater percentage of pork chops as acceptable when graded “choice”, had a greater ultimate pH, or when cooked to 63°C compared with chops that graded “standard”, had a lesser pH, or when cooked to 71°C or 82°C.

Materials and Methods

Pigs from both experiments were slaughtered at commercial facilities under the supervision of the USDA Food Safety and Inspection Service. Boneless loins were purchased from those facilities and transported to the University of Illinois Meat Science Laboratory. Therefore, Institutional Animal Care and Use Committee approval was not obtained. Sensory procedures for all consumer evaluations were reviewed and approved by the University of Illinois Office for the Protection of Research Subjects.

Experiment 1

Loins used in experiment 1 were from a commercial feeding trial that evaluated a feed additive intended to improve gut health (data not published). Pork quality measurements were conducted on 14 d aged loins including: visual color, visual marbling, subjective firmness, instrumental color, and ultimate pH. There were no differences between treatments for any loin quality trait ($P \geq 0.23$). Therefore, dietary treatments were disregarded during the allocations of loins to treatments for sensory evaluation. Loins were categorized using the previously proposed USDA quality grades based on NPPC visual color and marbling scores. Chops were classified as “choice” when NPPC visual color score was ≥ 3 and visual marbling score was ≥ 2 or “standard” when either NPPC color or marbling score minimums were not met (USDA, 2017). Candidate loins were targeted to have an ultimate pH range of 5.65 to 5.80 (category C as defined by

Lonergan et al. 2007). Due to the number of loins available in each quality grade, the pH range was slightly altered to an ultimate pH range of 5.64 to 5.76. In total, 24 loins that graded "choice" and 24 loins that graded "standard" were selected for consumer sensory evaluation (Table 1). Loins were cut into 2.54 cm thick chops using a push-feed style Treif Puma slicer (Treif model 700 F; Treif, Oberlahr, Germany). Chops were vacuum packaged and stored at -20°C until sensory evaluation. Two chops from each loin were randomly assigned to ending cooking temperatures of 63°C or 71°C.

Experiment 2

Loins used in experiment 2 were from the same population of pigs described previously by Richardson et al. (2018). The objective of that experiment was to determine effects of ultimate pH and visual color on trained sensory panel traits of pork loin chops cooked to an internal temperature of 63°C. Loins, described by Richardson et al. (2018) were sorted into different pH bins based on historical pH categories described by Lonergan et al. (2007): category A >5.95, category B ≥5.80 to 5.95, category C ≥5.65 to 5.80, category D ≥5.50 to 5.65, and category E <5.50. Loins were sorted according to the ultimate pH of the loin muscle assessed at 1 d postmortem. Loins were selected from categories A and B to represent the high pH treatment group and from categories D and E to represent the low pH treatment group. High pH loins had an ultimate pH range of 5.88 to 6.23 (Table 2). Low pH loins had an ultimate pH range of 5.36 to 5.56. Twenty six loins were selected from the high pH treatment group and 26 loins were selected for the low pH treatment group. Loins were aged until 16 d postmortem and were then cut into 2.54 cm thick chops, vacuum-packaged, and stored at -20°C until further analysis. Three chops from each loin were randomly assigned to 1 of 3 ending cooking temperatures: 63°C, 71°C, and 82°C.

Consumer Sensory Panels

All consumer sensory panels were conducted at the University of Illinois Meat Science Laboratory. Flyers and emails were sent out through the university to assemble a pool of consumers for both experiments. Willing participants were given a link to fill out an online survey informing investigators of their age, gender, race, and education level (Table 3 and 4). Along with demographic information, time availability was record for each participant. Once the online survey closed, participants were assigned panels. Participants were only allowed to participate once on each experiment, but some consumers did participate on both experiments. Panels were scheduled during 7 evaluation days. Each day included seven 20 minute sensory panels that used up to 6 panelists per sensory session. Frozen chops were placed into boxes according to their assigned serving day. Chops for both experiments were removed the freezer 24 hours prior to each panel. Water baths were warmed using an immersion heater sous-vide device (ANOVA Precision Cooker, Anova Applied Electronics, San Francisco, CA) and set to 63°C or 71°C for experiment 1 and 63°C, 71°C or 82°C for experiment 2. Chops were cooked using a sous-vide approach because the method is becoming increasingly more popular among consumers (Baldwin, 2012). An hour and a half before each panel started, chops were removed from the refrigerator (still in the vacuum-sealed bag) and placed into their assigned water bath. Water bath temperatures were monitored and adjusted when needed throughout the cooking process. Upon arrival, participants completed a wavier form informing them of the task they agreed to complete. After forms were signed and all participants were present, a monitor welcomed the group. A brief instruction session preparing participants for the sensory panel included a description of the sensory booths and what they needed to do with the material they were provided and instructions familiarizing each panelist with the evaluation forms. Once all consumer participants arrived, packaged chops were removed from the water bath. Chops were removed from their packages and final internal temperatures were measured using a meat thermometer. Chops were then placed in a sample sizer and sliced into 1cm ×1cm ×2.54 cm samples. Two pieces from each chop were placed into a small plastic cups with a numbered lid.

Panelists were seated in a breadbox style sensory booth room under red light to mask color differences among the samples. Panelist were provided a writing utensil, napkin, water, unsalted crackers, and an empty cup for any non-swallowed samples. A nine point Likert-type scoring system was used where 1 was extremely tough, extremely dry, extremely bland, and unacceptable, 5 was neutral for tenderness, juiciness, flavorful, and acceptability, and 9 was extremely tender, extremely juicy, extremely flavorful, and acceptable. For experiment 1, each panelist was served 4 samples (Choice, 63°C; Choice, 71°C; Standard, 63°C; Standard, 71°C) in a randomized order. For experiment 2, each panelist was served 6 samples (High pH, 63°C; High pH, 71°C; High pH, 82°C; Low pH, 63°C; Low pH, 71°C; Low pH, 82°C) in a randomized order. Samples were served to panelists one at a time through a small door on each of the sensory booths. Once all samples were served and evaluated, panelist exited the booth and returned the evaluation forms to the monitor.

Statistical Analysis

Data from each panel were entered into Excel (Microsoft, 2016) for each of the panelists using the score they provided for each sample in regards to tenderness, juiciness, flavor, and overall acceptability. The scoring was sorted into three categories. Scores1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Each experiment was treated as an independent data set, but all data were analyzed using the GLIMMIX procedure of SAS (SAS Inst. In., Cary, NC). Experiment 1 was analyzed using a model that included quality grade, degree of doneness, and the interaction. Experiment 2 was analyzed using a model that included pH category, degree of doneness, and the interaction. Panel was a random variable for both experiments. No significant interactions were detected for any parameter for either experiment. Therefore, only main effects were reported. All means were separated using the PDIFF option and were considered significantly different at $P < 0.05$. Means represent the percentage of panelists that reported findings in each of the 3 scoring categories.

Results

Experiment 1

Demographic summary data from experiment 1 are provided (Table 3). White ethnic origin and ages between 36-55 years old were the majority of consumers (83.5% and 42.9% respectively). Completed an advanced or graduate degree was the most common education level among consumers (42.9%). Gender was slightly skewed toward female (55.6%) compared with males (44.4%).

Only one significant interactions (P =0.02) between degree of doneness and quality grades for consumer overall neutral acceptability was detected. There were no differences in the percentage of choice chops rated neutral but a greater percentage of consumers rated standard chops cooked to 71°C as neutral compared with standard chops cooked to 63°C ($P < 0.001$). Quality grade had no effect ($P \geq 0.26$) on tenderness, juiciness, flavor, or acceptability of cooked pork chops regardless of temperature. A greater percentage ($P < 0.001$) of consumers rated chops cooked to 63°C to be tender (61.27%), juicy (61.66%), and flavorful (32.87%) compared to chops cooked to 71°C. Overall, 47.78% of consumers rated chops cooked to 63°C to be acceptable ($P < 0.001$) compared with only 17.90% of consumer acceptability of chops cooked to 71°C.

Experiment 2

Demographic summary data from experiment 2 are provided (Table 4). The majority of consumers were of white ethnic origin (83.2%) and between the ages of 36-55 years old (35.88%). Gender was nearly equally represented between males (49.6%) and females (50.4%). Completed an advanced or graduate degree was the most common education level among consumers (38.2%).

There were no interactions ($P \geq 0.19$) between ultimate pH and degree of doneness for any consumer sensory trait (Table 6). A greater ($P < 0.01$) percentage of consumers rated chops with a high pH (36.07%) as juicy compared with the percentage of consumers that rated chops with a low pH (24.29%) as juicy (Table 6). Tenderness, flavor, and overall acceptability were not influenced ($P \geq 0.13$) by ultimate pH.

Nearly 9% (8.48%) of consumers reported chops cooked to 71°C to be not tender compared with only 0.87% of consumers rating chops cooked to 63°C as not tender. Conversely, 81.25% of consumers rated chops cooked to 63°C as tender. Whereas, only 49.05% of consumers rated chops cooked to 71°C as tender.

Nearly 20% (19.51%) of consumers reported chops cooked to 71°C to be not juicy compared with only 3.06% of consumers rating chops cooked to 63°C as not juicy. Conversely, 70.61% of consumers rated chops cooked to 63°C as juicy. Whereas, only 24.41% of consumers rated chops cooked to 71°C as juicy.

Nearly 20% (17.90%) of consumers reported chops cooked to 71°C to be not flavorful compared with only 10.23% of consumers rating chops cooked to 63°C as not flavorful.

Conversely, 39.83% of consumers rated chops cooked to 63°C as flavorful. Whereas, only 22.50% of consumers rated chops cooked to 71°C as flavorful.

Nearly 10% (9.59%) of consumers reported chops cooked to 71°C to be not acceptable compared with only 2.77% of consumers rating chops cooked to 63°C as not acceptable. Conversely, 61.82% of consumers rated chops cooked to 63°C as acceptable. Whereas, only 30.61% of consumers rated chops cooked to 71°C as acceptable.

Discussion

Fresh color and visual marbling are used as indicators of tenderness and juiciness by consumers when they are evaluate pork products for purchase (Wood et al., 2004; Lonergan et al., 2007). Because of this, the USDA proposed a quality grading system using NPPC visual color and marbling scores (USDA, 2017) as a means of providing consumers a tool to aid in selection of fresh pork chops. However, for this grading system to be successful, color and marbling need to be associated with a positive eating experience. To date, nearly all reports evaluating the relationships between color and marbling with eating experience have used trained sensory panelists rather than consumers. Further, only limited data are available to determine consumers' preferences when chops were cooked to 63°C rather than 71°C.

For the present study, chops were assigned to 1 of 2 quality grade categories, choice or standard. Consumers were unable to detect sensory tenderness, juiciness, or flavor differences between the quality grades. These results are consistent with a previous trained sensory panel study that cooked chops to 63°C. Wilson et al. (2017), reported that extractable lipid and instrumental color were independently poor predictors of sensory traits in pork loin chops cooked to 63°C. Additionally, Wilson et al. (2017) reported trained sensory panelist were unable to detect differences in tenderness or juiciness among chops categorized into "quality grades" of high, medium and low quality grading system. If the classification system of Wilson et al. (2017) was used on the loins of the present study, then the standard loins would be "low quality" and the choice loins "medium quality".

Color and marbling are most often used as indicators of eating quality, but recent results do not support these relationships. Lowell et al. (2017) reported cook loss percentage ($r \leq |0.22|$) and instrumental tenderness ($r \leq |0.26|$) were not correlated with instrumental color or visual color when chops were cooked to 68℃. No instrumental or visual color parameters were moderately or strongly correlated with instrumental tenderness or cook loss in chops cooked to a range of 63℃ to 71℃ as described in Harsh et al. (2018). Rincker et al. (2008) reported a positive, but weak, relationship between sensory traits and marbling that only accounted for 13% of variation explained by those measurements with chops cooked to 71℃.

In contrast to these results, Cannata et al. (2010) reported trained sensory panelist rated chops with greater marbling (3.56%) as more juicy and tender compared to chops with less marbling (1.96%) of marbling when chops were cooked to 71℃. Another study reported consumers rated chops with 3-3.5% extractable lipid content as more tender and juicy than chops with ≤1% extractable lipid when chops were cooked to a 71°C internal temperature (Brewer et al., 2001). In both studies described above, the extractable lipid levels of the "high" treatments were greater than the mean extractable lipid (2.62%) of the "choice" quality grade used in the present study. In fact, the amount of extractable lipid of the "high" treatment group would rate as "Prime" in the proposed quality grading system.

Though the hypothesis for the present study was that chops grading choice would rate more tender, juicy, flavorful, and overall more acceptable compared to standard chops, this was not the case. One explanation for this lack of difference in eating experience is the similar color of standard and choice chops in this study. Because both color and marbling requirements must be met for chops to be labeled choice, standard chops did meet the color requirement (NPPC color score of ≥3) but not the marbling requirement (NPPC marbling score of ≥2). This resulted in similar color scores ad objective color readings between standard and choice chops. Future research should include prime, choice, select, and standard quality grades using the USDA proposed quality system. In today's industry, finding a well-controlled population that ranges from prime to select quality grades might prove difficult but would provide good additional information to the present study.

An additional objective of the present study was to determine the influence of ultimate pH on consumer perceptions of pork chop sensory traits. Previously, ultimate pH of pork chops was positively correlated with visual color and sensory tenderness (Huff-Lonergan et al., 2002). Additionally, increasing ultimate pH of fresh pork chops increased sensory tenderness and juiciness of chops cooked to 71°C (Lonergan et al., 2007). This is similar to the present study where a greater percentage of consumers rated the high pH treatment juicy compared to the low pH treatment. However, no other consumer sensory traits were different between the pH treatments. Results of the present study are similar to those of Richardson et al. (2018) who reported no differences in sensory tenderness between chops of different ultimate pH when chops were cooked to 63°C, until pH exceeded 5.95. Chops with ultimate pH greater than 5.95 were more tender than all other pH categories. However, consumers in the present study did not find pork chops from the "high" pH category to be more tender. In the present study, this "high" category included loins with ultimate pH ranging from 5.88 to 6.23, therefore not as extreme as the high pH loins in the previous study.

While consumers were not able to detect differences in tenderness between pH treatments or quality grades, they were able to detect differences in tenderness between chops cooked to different degrees of doneness. The USDA recently changed the final internal temperature to cook whole pork muscles from 71°C to 63°C (FSIS, 2013). The pork production industry has changed over the years to an indoor commercial setting eliminating the risk of contamination via *Trichinella sprilis*, allowing for a lower endpoint cooking temperature (Pyburn et al., 2005). In this present study, both previously established and revised cooking temperatures were used to assess their effect on consumer sensory traits. Regardless of pH treatment or quality grade, consumers rated chops cooked to 63°C more tender, juicy, flavorful, and overall acceptable compared to chops cooked to a higher degree of doneness. Rincker et al. (2008) reported, as final internal cooking temperature increases from 62°C to 80°C, trained sensory tenderness and juiciness decreases from 8.56 to 6.81 and 9.85 to 6.29, respectively. Rincker et al. (2008) also reported a linear relationship between consumer tenderness and juiciness scores and visual marbling score, in chops cooked to 71℃. However, results from the present study indicate that it is the final internal temperature that impacts overall eating experience, not quality grade (visual color and visual marbling).

Public acceptance and application of the revised cooking temperature will require both time and education. According to focus groups conducted by FSIS (1998), consumers do not regularly use meat thermometers. Other methods such as the “eye ball” method, cooking until no red or pink is inside, or until juice or fluids run clear were among the reported methods used by consumers to check their meat. Focus groups also reported that they would use a meat thermometer if it would enhance the flavor or quality of the product they were preparing. Consumers need to be educated on the importance of the meat thermometer and the ideal temperature to cook whole pork muscles. Font-i-Furnols and Guerrero (2014), explained that a consumer's behavior towards meat and meat products can be affected by three main factor categories: marketing, psychological, and sensory factors. Visual appearance (color and marbling) of the meat is a sensory factor that was discussed earlier. Additionally, psychological factors may include beliefs of meat that were formed by observations, information, or inferences can all influence consumer preferences (Font-i-Furnols and Guerrero, 2014). Education on proper cooking techniques and cooking temperatures of pork products, with the use of a meat thermometer, will help to ensure consumers have a positive eating experience and become a repeat consumer.

In conclusion, ultimate pH has little impact on consumer sensory traits except for juiciness which increases with increasing ultimate pH. A proposed quality grade system would not guarantee superior eating experience with higher quality grades. Additionally, a lower final internal temperature of whole pork muscles will improve tenderness, juiciness, flavor, and overall consumer acceptability. Overall, ultimate pH and "quality grades" did not impact consumer sensory traits of pork loin chops that cooked to 63°C. Regardless of the visual color or marbling of a pork chop in the retail case, preparation of the chop by the consumer has a greater impact than the pork chop that is purchased.

Tables

Table 2.1 Effects of proposed USDA quality grade categories on chop quality
characteristics

	Quality grade[1]			
Item	Choice	Standard	SEM	*P*-value
Subjective evaluations[2]				
Visual color	3.3	3.3	0.07	0.66
Visual marbling	2.4	1.4	0.07	<0.0001
Subjective firmness	2.8	2.5	0.16	0.36
Instrumental color[3]				
Lightness, L*	50.60	50.71	0.64	0.91
Redness, a*	8.27	8.25	0.32	0.96
Yellowness, b*	3.00	2.80	0.20	0.50
Ultimate pH	5.70	5.70	0.01	0.92
Extractible lipid, %	2.62	1.52	0.14	<0.0001

[1]Choice chops had visual color scores ≥ 3 and visual marbling scores ≥ 2. Standard chops were those that did not meet the minimum criteria for either visual color or visual marbling

[2]NPPC color using the 1999 standards, half point scale where 1 = visually palest; and 6 = visually darkest.

[2]NPPC marbling using the 1999 standards where 1 = visually the least marbling and 6 = visually the most marbling

[2]NPPC firmness using the 1991 standard where 1 = softest and 6 = firmest

[3]L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color)

Table 2.2 Effects of ultimate pH categories on 16 d loin quality characteristics

	Ultimate pH[1]			
Item	High	Low	SEM	*P*-value
Ultimate pH	6.00	5.52	0.02	<0.0001
Subjective evaluations[2]				
Visual color	3.8	3.1	0.10	<0.0001
Visual marbling	2.8	2.2	0.14	<0.01
Subjective firmness	3.3	3.2	0.11	0.62
Instrumental color[3]				
Lightness, L*	42.00	47.77	0.64	<0.0001
Redness, a*	9.05	9.52	0.19	0.08
Yellowness, b*	3.16	5.65	0.25	<0.0001

[1]High ultimate pH range of 5.88 to 6.23, low ultimate pH ranged 5.36 to 5.56 measured on day 1 postmortem

[2]NPPC color using the 1999 standards, half point scale where 1 = visually palest; and 6 = visually darkest.

[2]NPPC marbling using the 1999 standards where 1 = visually the least marbling and 6 = visually the most marbling

[2]NPPC firmness using the 1991 standard where 1 = softest and 6 = firmest

[3]L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color).

Table 2.3 Demographic summary of participating consumers (n = 133) evaluating the effects of proposed USDA quality grade and degree of doneness

Characteristic	Response	Percentage of consumers
Age		
	18-25 years old	12.8
	26-35 years old	13.5
	36-55 years old	42.9
	56-75 years old	30.1
	76 years old or older	0.8
Ethnic origin		
	Asian/ Pacific Islander	10.5
	Black or African American	1.5
	Hispanic or Latino	0.8
	Other	3.8
	White	83.5
Gender		
	Female	55.6
	Male	44.4
Education level		
	Completed an advanced or graduate degree	42.9
	Some graduate school	12.0
	Completed an undergraduate degree	27.8
	Some college	15.0
	High school diploma	2.3

Table 2.4 Demographic summary of participating consumers (n = 131) evaluating the effects of loin ultimate pH and degree of doneness

Characteristic	Response	Percentage of consumers
Age		
	18-25 years old	10.7
	26-35 years old	20.6
	36-55 years old	35.9
	56-75 years old	31.3
	76 years old or older	1.5
Ethnic origin		
	Asian/ Pacific Islander	10.7
	Black or African American	0.8
	Hispanic or Latino	3.1
	Other	2.3
	White	83.2
Gender		
	Female	50.4
	Male	49.6
Education level		
	Completed an advanced or graduate degree	38.2
	Some graduate school	14.5
	Completed an undergraduate degree	23.7
	Some college	22.9
	High school diploma	0.8

Table 2.5 Effects of degree of doneness (DOD) and proposed USDA quality grade on consumer sensory traits of pork chops[1,2]

	Quality grade[3]		Degree of doneness			*P*-value		
	Choice	Standard	63°C	71°C	SEM	Quality grade	DOD	Quality grade × DOD
Consumer tenderness								
Not tender	13.07	13.08	6.34	24.98	3.62	0.99	<0.001	0.40
Neutral	42.28	41.76	32.13	52.60	3.36	0.91	<0.01	0.08
Tender	38.59	39.60	61.27	20.66	4.53	0.83	<0.001	0.26
Consumer juiciness								
Not juicy	13.53	10.45	4.75	26.80	3.68	0.36	<0.001	0.30
Neutral	45.57	45.23	33.46	57.90	3.16	0.94	<0.001	0.79
Juicy	32.69	34.48	61.66	13.71	4.48	0.71	<0.001	0.93
Consumer flavor								
Not flavorful	22.92	18.80	15.68	27.03	3.28	0.26	<0.01	0.24
Neutral	52.24	55.63	50.73	57.12	3.15	0.44	0.15	0.79
Flavorful	23.66	22.30	32.87	15.37	3.29	0.72	<0.001	0.20
Overall acceptability								
Not acceptable	10.45	10.78	6.07	17.90	2.96	0.91	<0.001	0.22
Neutral	56.79	56.71	45.63	67.22	3.45	0.99	<0.001	0.02
Acceptable	27.79	27.54	47.78	13.77	4.06	0.96	<0.001	0.11

[1]Values reported are a percentage of responses for each of the main effects

[2]Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were consider neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable.

[3]Choice chops had visual color scores ≥ 3 and visual marbling scores ≥ 2. Standard chops were those that did not meet the minimum criteria for either visual color or visual marbling.

Table 2.6 Effects of degree of doneness (DOD) and ultimate pH on consumer sensory traits of pork chops[1,2]

	Ultimate pH[3]		Degree of doneness				*P-value*		
	High	Low	63°C	71°C	82°C	SEM	pH	DOD	pH × DOD
Consumer tenderness									
Not tender	4.28	6.32	0.87[c]	8.48[b]	17.00[a]	3.16	0.36	<0.001	0.87
Neutral	34.80	36.06	18.89[c]	40.87[b]	50.64[a]	3.67	0.73	<0.001	0.50
Tender	56.46	52.81	81.25[a]	49.05[b]	29.52[c]	4.64	0.37	<0.001	0.42
Consumer juiciness									
Not juicy	14.17	16.99	3.06[c]	19.51[b]	44.82[a]	5.11	0.41	<0.001	0.26
Neutral	38.45	41.81	27.11[b]	51.19[a]	43.52[a]	3.33	0.35	<0.01	0.19
Juicy	36.07	24.29	70.61[a]	24.41[b]	9.03[c]	4.91	<0.01	<0.001	0.93
Consumer flavor									
Not flavorful	18.82	16.10	10.23[c]	17.90[b]	27.40[a]	4.08	0.33	<0.01	0.45
Neutral	54.17	52.64	47.87	56.34	55.96	3.41	0.67	0.10	0.52
Flavorful	21.15	26.07	39.83[a]	22.50[b]	13.15[c]	4.59	0.13	<0.001	0.44
Overall acceptability									
Not acceptable	8.49	9.98	2.77[c]	9.59[b]	25.68[a]	4.18	0.53	<0.001	0.96
Neutral	48.16	50.06	35.74[b]	57.14[a]	54.79[a]	3.67	0.61	<0.001	0.93
Acceptable	36.44	31.87	61.82[a]	30.61[b]	16.27[c]	4.62	0.23	<0.001	0.95

[a,b] Least square means within a row among main effects lacking a common superscript differ (P <0.05)

[1]Values reported are a percentage of responses for each of the main effects

[2]Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were consider neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable.

[3]High ultimate pH ranged from 5.88 to 6.23, low ultimate pH ranged from 5.36 to 5.56

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CHAPTER 3

THE EFFECTS OF COOKING METHOD AND COOKED COLOR ON CONSUMER ACCEPTABLITY OF BONELESS PORK CHOPS

Abstract

The objective was to determine the effects of cooking method and degree of doneness on consumer eating experience of pork chops when able to observe differences in cooked color. The hypothesis was that when consumers were able to visualize cooked color, they would rate pork cooked to 63°C less acceptable than chops cooked to 71°C due to historical perceptions of pork degree of doneness. Additionally, consumers would find sous-vide cooked chops less acceptable compared with gilled chops due to the lack of browning. Pork chops were cooked to either 63°C or 71°C using either an open-hearth grill or an immersion cooker sous-vide device. Consumers (132 total) were provided 4 samples (Grill, 63°C; Sous-Vide, 63°C; Grill, 71°C; Sous-Vide, 71°C). Cooked color was measured with a Minolta chroma meter to determine instrumental color. Consumers were seated in a breadbox style sensory booth room under white light to allow for cooked color appraisal. Consumers used a 9-point Likert-type score system to determine tenderness, juiciness, flavor, and overall acceptability. Data were organized as a percentage of responses and analyzed using the GLIMMIX procedure of SAS with a model including cooking method, degree of doneness, and the interaction. Chops cooked to 63°C (a^* = 4.10) were more red ($P = 0.01$) than chops cooked to 71°C (a^* = 3.82). Consumers rated a greater percentage ($P < 0.001$) of chops cooked sous-vide at 63°C as tender (82.82%), juicy (55.83%) and acceptable (60.34%) compared with all other cooking method and degree of doneness combinations. Consumers rated a greater ($P < 0.04$) percentage of chops cooked sous-vide as tender and acceptable compared to chops grilled. Consumers rated a greater ($P < 0.01$) percentage of chops cooked grill as not juicy compared to chops grilled. Contrary to the

hypothesis, ratings for flavor did not differ between cooking methods ($P = 0.88$).Consumers rated a greater ($P < 0.01$) percentage of chops as tender, juicy, flavorful, and acceptable when cooked to 63℃ compared to 71℃.Even when consumers can identify cooked color, they preferred chops cooked to 63°C. Consumers rated a greater percentage of chops cooked to 63℃ using sous-vide as more tender, juicy, and acceptable than any other combination of cooking method and degree of doneness. Lack of browning using a sous-vide cooking method did not compromise eating quality of chops compared to grilling.

Introduction

According to the American Meat Science Association (**AMSA**) sensory guidelines, broiling is the preferred cooked meats preparation method by researchers because it closely replicates the method commonly used by consumers (AMSA, 2015). Sous-vide method is becoming increasingly more popular among consumers (Baldwin, 2012). Advantages of sous-vide cooking is the product is cooked longer allowing the meat to become more tender without cooking over the desired internal temperature set by the immersion cooker (Baldwin, 2012). However, using a sous-vide cooking method does not allow for the Malliard reaction causing browning on the surface of the meat or cooked flavor of meat. (Ruiz-Carrascal et al. 2019). Rinker et al. (2008) broiled pork chops to evaluate sensory tenderness of pork chops cooked to 62 °C compared with chops cooked to 71°C or 80°C, and reported increased sensory tenderness scores as internal temperature decreased from 80℃ to 62℃. Because of the improvement in sensory without compromising food safety, in 2011 the United States Department of Agriculture (USDA) revised the recommended final internal cooking temperature of whole pork muscles from 71℃ to 63℃. Honegger et al. (2019) reported 47.78% of consumers rated pork chops cooked to 63℃ as acceptable compared to only 13.77% of consumers rated chops cooked to

71°C as acceptable. Consumers were served under red lighting to mask any color differences between different degrees of doneness. Lien et al. (2002) reports that as internal temperature increases, pork will appear less pink internally. Historically, in place of a meat thermometer, consumers will use the “eye ball” method or cook pork until no red or pink is present on the center (FSIS, 1998). There are limited data on the effect of cooking method and degree of doneness on consumer acceptability of pork chops when consumers are given the chance to visually apprise the chop and then evaluate sensory characteristics. Therefore, the objective was to determine the effect of cooking method and degree of doneness on consumer eating experience of pork chops when consumers were able to observe differences in cooked color. The hypothesis was that when consumers were able to visualize cooked color, they would rate pork cooked to 63°C less acceptable than chops cooked to 71°C due to historical perceptions of pork degree of doneness. Additionally, consumers would find sous-vide chops less acceptable due to the lack of browning compared to grilled chops.

Materials and Methods

Pigs were slaughtered at a commercial facility under the supervision of the USDA Food Safety and Inspection Service. Boneless loins were purchased from the facility and transported to the University of Illinois Meat Science Laboratory. Therefore, no Institutional Animal Care and Use Committee approval was needed. Sensory procedures for consumer evaluations were reviewed and accepted by the University of Illinois Office for the Protection of Research Subjects prior to recruitment.

Loin Origin

Loins were visually selected at the abattoir to represent an average pork loin for visual color (NPPC score 2-3) and visual marbling (NPPC score 2-3) and then vacuumed-sealed. Boneless loins (12 total) were purchased from that facility and transported to the University of Illinois Meat Science Laboratory. Upon arrival, loins were aged until 10 d postmortem, then frozen as whole loins at -20°C until further analysis. Prior to consumer sensory panels, frozen loins were removed from the freezer. Loins were cut into 3.2 cm thick chops using a Biro Meat Saw (model 3334, The Brio MGF. Co, Marblehead, Ohio, USA) beginning at anterior end of the loin. Chops containing the spinalis doris muscle were excluded and the first 9 chops posterior to the spinalis dorsi muscle were cut and saved from each loin for consumer evaluation. Chop 1 (chop at approximately the area of the 10^{th} rib) was used for quality measurements and then discarded after evaluation. Chop 2, 3, 4, and 5 were cut and randomly assigned one of four cooking method and degree of doneness combinations: Grill, 63°C; Sous-Vide, 63°C; Grill, 71°C; Sous-Vide, 71°C. Chop 6, 7, 8, and 9 were cut and randomly assigned one of four cooking method and degree of doneness combinations previously described above. A total of 12 chops were cut for quality measurements and a total of 96 chop were cut for sensory evaluations. Frozen chops were vacuum packaged, placed into boxes according to assigned panel, and stored at -20℃ until sensory evaluations. Twenty-four hours prior to each panel, the assigned panel box was removed from the freezer and chops were allowed to thaw at 4℃.

Consumer Sensory Panels

Consumer sensory panels were conducted at the University of Illinois Meat Science Laboratory. To assemble a pool of consumers for these panels, email lists and flyers were used for recruitment. Consumers were asked to fill out an online survey regarding their demographic information [age, gender, race, and education level (Table 1)]. Additionally, consumers recorded their availability for scheduled evaluation days. Each of the 3 evaluation days had a total of 8 panels lasting a total of 30 minutes per panel. Each panels could accommodate up to 8 consumers at a time. Four hours prior to the first panel of the day, warm water baths were started using an immersion heater sous-vide device (ANOVA Precision Cooker, Anova Applied Electronics, San Francisco, CA). This cooking method was used for 2 of the 4 treatments and water baths were set to either 63°C or 71°C. Vacuumed sealed chops were placed into warm water baths 2 hours prior to each panel. Temperatures for the warm water baths were monitored and adjusted accordingly during the cooking process. Each panel had a total of 4 chops, the remaining two chops were cooked on a Farberware Open Hearth grill (model 455N, Walter Kidde, Bronx, NY, USA). Chops were monitored using a copper-constantan thermocouples (Type T, Omega Engineering, Stamford, CT, USA) connected to a digital scanning thermometer (model 92000-00, Barnat Co, Barrington, IL). Thermocouples were placed in the geometric center of the chop and placed on the grill. Chops remained on the grill until the internal temperature reached 31.5°C or 35.5°C, flipped to the other side, then remained on the grill until chops reach either 63°C or 71°C. Chops were removed from the grill or water bath and final internal temperatures were measured using a meat thermometer. Chops were sliced in the middle of the chop to expose the center of the chop. A Minolta CR-400 Chroma meter (Minolta Camera Co., Ltd., Osaka, Japan) using a D65 light source, 2° observer angle, an 8 mm aperture, and calibrated using a white tile was used to measure instrumental cooked chop color. Instrumental color readings included: lightness (L*), redness, (a*), and yellowness (b*; CIE 1978) to measure cooked color of each chop. Chops were placed in a sample sizer and sliced into 1cm ×1cm ×3.2

cm samples. Two pieces from each chop were placed in a small plastic cup with a numbered lid before being served to consumers.

Upon arrival, consumers were given a packet with instructions. First, informed consent forms were signed before the panel session could begin. Once all consumers were present and signed consent, a pre-survey was given with 7 questions. Question one and two asked consumers to select one of the answers to how many times they ate and cooked pork: more than once a week, once a week, 2-3 times a month, once a month, or less than once a month. Question 3 asked consumers to select all the ways they used to cook pork from the following answers: stove top, oven, grill, air fryer, deep fryer, slow cooker, sous-vide, or other. Question 4 asked consumers to select all the ways they used to determine when pork is done and safe to consume at home from the following answers: use a meat thermometer, look at the color of the meat, cook until juices runs clear, cook for a specific amount of time, I do not check to see if it is done, or other. Questions 5 asked consumers to evaluate a set of degree of doneness photos that ranged from rare to well done and then select the photo that represented their degree of doneness preference from the following photos: rare, medium rare, medium, medium well, and well done. Question 6 asked consumers to select the main reason why they chose the degree of doneness preference from the previous question from the following answers: best flavor, best texture, juiciest, safest to consume, and other. The final question asked consumers to circle what temperature they believed pork is safe to consumer, temperatures ranged from 100°F to 200°F and increased in 5°F increments. After completion of the pre-survey, a brief set of instructions were given to consumers regarding the evaluation sheet and what to expect during the sensory panel. Consumer were seated in a breadbox style sensory booth room under white florescent light to allow for consumers to not be blinded to cooked color. In each sensory booth, consumers were provided unsalted crackers and water to use as palette cleansers between samples. Consumers were asked to rate each chop for tenderness, juiciness, flavor, and overall acceptability. A nine point Likert-type scoring system was used where 1 was extremely tough, extremely dry, extremely bland, and unacceptable, 5 was neutral for tenderness, juiciness, flavorful, and acceptability, and 9 was extremely tender, extremely juicy, extremely flavorful, and acceptable. Each consumer within a panel was served 4 samples (Grill, 63°C; Sous-Vide, 63°C; Grill, 71°C; Sous-Vide, 71°C) in a randomized order.

Once all samples were served and evaluated by consumers, consumers were asked to bring their evaluation sheets to the monitor. A monitor then revealed cooking methodology and degree of doneness for each sample to the consumers. Once all the samples identities were revealed, the monitor ask consumers to discuss how they ranked chops and compare with how the chops were prepared. Consumers were asked to fill out a post survey to determine if views and beliefs of consumers changed over the course of the session. Post-survey questions included some of the same questions from the pre-survey, including asking consumers to evaluate a set of degree of doneness photos that ranged from rare to well done and then select the photo that represented their degree of doneness preference from the following photos: rare, medium rare, medium, medium well, and well done. Next question asked consumers to select the main reason why they chose the degree of doneness preference from the previous question from the following answers: best flavor, best texture, juiciest, safest to consume, and other. The final question asked consumers to circle what temperature they believed pork is safe to consumer, temperatures ranged from 100°F to 200°F and increased in 5°F increments.

Statistical Analysis

Summary statistics for loin quality measurements were calculated using the MEANS procedure of SAS (SAS Inst. In., Cary, NC). Cooked color data were analyzed using the MIXED procedure of SAS using the model including cooking method, degree of doneness, and the interaction between cooking method and degree of doneness. All means were separated using the PDIFF option and were considered significantly different from 0 at $P < 0.05$. Panelist scores for each sample in regards tenderness, juiciness, flavor, and overall acceptability were entered into Excel (Microsoft, 2016). The scoring was sorted into three categories. Scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Data were analyzed using the GLIMMIX procedure of SAS using cooking method, degree of doneness, and the interaction. Panel served as a random variable. Means were separated using the PDIFF option and were considered significant at $P < 0.05$. These means represented the percentage of panelist who were represented in each of the three scoring categories. Survey results were divided into pre and post survey questions. Pre and post-survey questions were analyzed using SPSS (IBM Corporation, Armonk, NY) and reported as frequencies and percentage of consumers responses for each question. Pre and post survey results from those questions were analyzed using a paired t-test in SPSS. Means were considered significantly different at $P < 0.05$.

Results

Demographic

Demographic summary data for 132 participants were provided (Table 1). White ethnic origin and ages between 36-55 years old were the majority of consumers (73.48% and 29.55%

respectively). Over 57% of all participants were over the age of 35 years old. Completed an advanced or graduate degree was the most common education level among consumers (43.18%). Gender was slightly skewed toward female (54.55%) compared with males (45.45%).

Loin quality

A total 96 chops from 12 loins (8 chops per loin; 2 chops per cooking method degree of doneness combination) were used for consumer sensory panels. Visual color scores averaged 3.58, visual marbling scores averaged 2.58, and subjective firmness scores averaged 2.67 for this population of loins (Table 2). Instrumental lightness (L*) averaged 48.89, redness (a*) averaged 5.85, and yellowness (b*) averaged 5.33 for this population of loins. The mean ultimate pH of 12 loins was 5.70.

Cooked Color

There were no significant interactions ($P \geq 0.09$) between cooking method and degree of doneness for lightness, redness, or yellowness (Table 3). However, chops cooked using sous-vide were 0.34 a* units more red ($P = 0.01$) and 0.33 b* units less yellow ($P = 0.01$) compared to chops cooked on a grill. Additionally, chops cooked to 63℃ were 0.28 a* units more red ($P = 0.03$) and 0.31 b* units less yellow ($P = 0.01$) compared to chops cooked to 71℃.

Consumer Sensory Traits

There were interactions between cooking method and degree of doneness for tenderness, juiciness, and overall acceptability. Therefore, percentage of consumers were expressed as interaction means (Table 4).

A greater ($P < 0.001$) percentage of consumers rated a chop cooked sous-vide 63℃ as tender compared with all other cooking method and degree of doneness combination. Additionally, a greater ($P = 0.05$) percentage of consumer rated a chop cooked grill 71℃ as not tender compared with all other cooking method and degree of doneness combinations. Chops cooked to 63℃ had a greater ($P < 0.0001$) percentage of consumers' rate chops as tender compared to chops cooked to 71℃. Additionally, chops cooked sous-vide had a greater ($P < 0.0001$) percentage of consumers rate chops as tender compared to chops cooked on the grill.

A greater ($P < 0.001$) percentage of consumers rated a chop cooked sous-vide 63℃ as juicy compared with all other cooking method and degree of doneness combination. Additionally, a greater ($P < 0.01$) percentage of consumer rated a chop cooked grill 71℃ as not juicy compared with all other cooking method and degree of doneness combinations. Chops cooked to 63℃ had a greater ($P < 0.0001$) percentage of consumers rate chops as juicy compared to chops cooked to 71℃. Additionally, chops cooked on the grill had a greater ($P < 0.01$) percentage of consumers rate chops as not juicy compared to chops cooked sous-vide.

Nearly 35% (34.61%) of consumers rated chops cooked to 63℃ as flavorful compared to only 24.31% of consumers rating chops cooked to 71℃ as flavorful. Cooking method did not impact consumer sensory flavor (P=0.30) nor was there an interaction between cooking method and degree of doneness (P=0.16) for sensory flavor.

A greater ($P = 0.01$) percentage of consumers rated a chop cooked sous-vide 63℃ as acceptable compared with all other cooking method and degree of doneness combination. Additionally, less than 3% (2.22%) of consumers rated a chop cooked sous-vide 63℃ as not acceptable compared to all other cooking method and degree of doneness combinations. Chops cooked to 63℃ had a greater ($P < 0.0001$) percentage of consumers rate chops as acceptable compared to chops cooked to 71℃. Additionally, chops cooked sous-vide had a greater ($P = 0.04$) percentage of consumers rate chops as acceptable compared to chops cooked on the grill.

Survey Results

Question 1 asked consumers to report on average how many times they ate pork each month (Table 5). The greatest percentage of consumers (40.6%) responded more than once a week followed by 2-3 times a month (29.3%), one a week (23.3%), once a month (4.5%) and finally only 2.3% of consumers eat pork less than once a month. Question 2 asked consumers to report on average how many times they cooked pork each month (Table 5). The greatest percentage of consumers (30.1%) responded more than once a week followed by 2-3 times a month (28.6%), one a week (19.5%), once a month (12.8%) and finally only 9% of consumers eat pork less than once a month.

Question 3 asked consumers to select the ways they used to cook pork (Table 5). Consumers could choose multiple answers, therefore the percentages are expressed as the number of responses divided by the total number of participants. The greatest percentage of consumers (80.5%) reported stove top as their cooking method followed by oven (68.4%), grill (66.9%),slow cooker (54.9%), deep fryer (8.3%), air fryer (6.8%), sous-vide (6.0%), and finally only 3.0% of consumers reported using other methods. Other cooking method included smoker, microwave, and instapot. Question 4 asked consumers to select ways they determine when pork is done and ready to consume (Table 5). Consumers could choose multiple answers, therefore the percentages are expressed as the number of responses divided by the total number of participants. The greatest percentage of consumers (67.7%) reported looking at the color of the meat as their way to determine doneness followed by using a meat thermometer (50.4%), cooking for a specific amount of time (33.1%), cooking until juices run clear (30.8%), other (6.8%), and finally 3.0% of consumer reported not checking to see if the pork is done. Other ways to check included firmness of the meat and a combination of specific time and temperature.

Questions 5 asked consumers to evaluated a set of photos and report which degree of doneness did they prefer (Table 6). In the pre-survey, over 50% (53.4%) of consumers choose medium pork chop as their preferred degree of doneness followed by medium well (19.5%), medium rare (16.5%), and only 15.8% of consumers preferred well done pork chops. Treating this as a continuous variable that ranged from 1 (rare) to 5 (well done), the mean preference for the pre-survey was 3.27 (Table 7). In the post-survey, only 43.6% of consumers preferred medium pork followed by medium rare (37.6%), medium well (12%), well done (6.8%), and only 0.8% of consumer's preferred rare pork. Treating this as a continues variable that ranged from 1 (rare) to 5 (well done), the mean preference for the post-survey was 2.84 (Table 7). A paired t-test identified that consumers preferred less well-done pork in the post-survey compared to pre-survey after participating in the sensory panel ($P < 0.01$).

Question 6 asked consumers why they chose the cut of pork from question 5 (Table 6). In the pre-survey, the greatest percentage of consumers responded that their preferred cut would be the juiciest (34.6%) followed by safest to consume (33.8%), best texture (22.6%), best flavor (21.8%), and only 5.3% of consumers choose that cut for other reasons. In the post-survey, the greatest percentage of consumers responded that their preferred cut would be the juiciest (45.1%) followed by best flavor (25.6%), best texture (24.1%), safest to consume (12.0%), and only 1.5% of consumers choose that cut for other reasons. Question 7 asked consumers to report at what temperature (in Fahrenheit) is safe to consume (Table 7). In the pre-survey the average temperature was 154.44 °F and in the post-survey average temperature was 144.84. A paired t-test found consumers believed that pork was safe at a lower temperature in the post-survey compared to the pre-survey ($P < 0.01$).

Discussion

For the present study, consumers were served chops cooked either using a broiling method (open hearth grill) or sous-vide cooking method. In a FDA consumer survey, 52.3% of participants used a grill/barbecue when preparing pork chops (FDA, 2016). Generally, researchers prefer to use a broiling method to best replicate the most common way that consumers will prepare meat (AMSA, 2015). However, sous-vide is a common cooking method used within the restaurant industry. This cooking method allows for chefs to hold meat at a constant temperature over a long period of time without the meat going above the desired temperature. Most commonly, chefs will cooking using sous-vide method then sear both sides of the meat to create a Maillard reaction (Baldwin, 2012; Ruiz-Carrascal et al., 2019). Cooked meat flavor is a product of the Maillard reaction which is a reaction between amino acids and sugars reducing (Baldwin, 2012). In the current study, the percentage of consumers rating chops as flavorful was not significantly different between cooking method. The current study served sous-vide chops without any browning before or after the sous-vide cooking process. The percentage of consumers rating chops as tender was greater for sous-vide cooking method compared to the grilling method. Sous-vide method has been known for a tender and juicy product and was to be expected. However, the initial hypothesis that sous-vide would be less desirable compared to the broiling method was not noted. A greater percentage of consumers rated chops cooked sous-vide as acceptable compared to chops cooked using the grilling method.

In 2011 the USDA lowered the recommended final internal cooking temperature of whole muscle pork cuts from 71°C to 63°C (FSIS, 2013). In recent research, degree of doneness has the greatest impact on overall eating experience. Ultimate pH did not affect trained sensory tenderness scores when chops are cooked to 63°C unless the ultimate pH is above 5.95

(Richardson et al., 2018). Wilson et al. (2017) reported that color and marbling independently do not effect eating experience of trained sensory panelist when chops are cooked to 63℃. Recent data reported that a greater percentages of consumers rated pork chops cooked to 63℃ as tender (81.25%), juicy (70.61%), flavorful (39.83%), and overall acceptability (61.82%) compared to pork chops cooked to 71℃ (Honegger et al., 2019). However, visual color of cooked pork chops will become less pink as internal cooking temperature increase (Lien et al., 2002). According to the pre-survey of the present study, consumers chose their preferred degree of doneness as medium. The greatest percentage for the reason why they chose that degree of doneness because it would be the juiciest (34.6%) followed by the safest to consume (33.8%). In the present study, consumers were asked how they determined when pork is done and ready to consume in a pre-survey. The greatest percentage of consumers responded that they looked at the color of the meat (67.7%) followed by using a meat thermometer (50.4%). In 1998, focus groups were conducted by FSIS to evaluated consumer behaviors. Consumers do not regularly use a meat thermometer and cooked pork until no red or pink is visible inside the meat (FSIS, 1998). The United States Food and Drug Administration (FDA) food safety survey of 2016 indicated 33% of consumers do not own a meat thermometer and those that do own one only 38% use it on large pieces of meat and only 10% on hamburgers (FDA, 2016). The hypothesis for the present study was that consumers would rate chops cooked to 63℃ as unacceptable compared to chops cooked to 71℃ because researchers allowed for consumers to appraise pork samples under white lighting. Typically if a trained or consumer panel involves a treatment that will create color differences within the panel, red lighting is used to mask the color differences that is visible to panelist (AMSA, 2015). The present study evaluated cooked color of all pork chops served to consumers. Chops cooked to 63℃ were more red compared to chops cooked to 71℃. Regardless of the visual color of the chops, a greater percentage of consumers still rated chops cooked to 63℃ as tender, juicy, flavorful, and overall acceptable compared to chops cooked to 71℃. Once consumers were educated that 63℃ was safe to consume, post-survey results indicated that a greater percentage of consumers chose medium rare as their preferred degree of doneness. Additionally, the percentage of consumers' reasoning for choosing their degree of doneness preference decreased for safe to consume (12.0%) and increased for flavor (25.6%), texture (24.1%), and juicy (45.1%) from pre- to post-survey results.

The interaction between cooking method and degree of doneness on the percentage of consumers rating sous-vide chops 63℃ as tender was greater from all other cooking method and degree of doneness combinations. Bryan et al. (2019) reports that sous-vide works as a method to detect differences in instrumental tenderness. In addition, Rinker et al. (2008) reports a 1.75 increase in tenderness scores of trained sensory panelist with decreasing internal cooking temperature. Additionally, percentage of consumers rating sous-vide 63℃ as juicy was greater from all other cooking method and degree of doneness combination. Klehm et al. (2018) reports a decrease in cook loss by 1.64% when cooking chops to 63℃ compared to 71℃. Rinker et al. (2008) reports a 3.56 increase in juiciness scores of trained panelist with decreasing internal cooking temperature. Sun et al. (2019) reports that sous-vide cooking will increase moisture retention. With an increase in percentage of consumers rating chops cooked sous-vide as tender and juicy, it is to be expected that the overall acceptance of pork chops cooked sous-vide 63℃ would be the greatest percentage compared to all other cooking method and degree of doneness combination. Although the foodservice industry has been using sous-vide cooking method since early 2000, consumers are becoming more aware of the cooking method since early 2010 (Baldwin et al., 2012). In addition to cooking method, degree of doneness has the greatest impact on overall eating experience. To encourage repeat purchasing of pork chops, cooking methods that will create a consistent and satisficing eating experience and proper cooking temperature are all important.

Conclusion

A lower final internal cooking temperature of pork chops increased the percentage of consumers rating chops as tender, juicy, flavorful, and overall acceptable. Even when consumers were given the opportunity to visually apprise the cooked chops, a greater percentage of consumers preferred chops cooked to 63℃ over 71℃. Sous-vide chops were more tender and a greater percentage rated acceptable compared to grilled chops. Further, the sous-vide 63℃ were the most tender, juicy, and acceptable compared with the other 3 cooking method and degree of doneness combination. Chops cook sous-vide did not compromise acceptability or sensory traits of pork chops due to lack of browning.

The survey results also indicated the consumer preferred a lower degree of doneness of pork after participating in the sensory panel and that they believed pork should be cooked to a lower temperature. Additionally, the participants were able to correctly identify the appropriate temperature to cook pork to for safety. Consumers were also less concerned about safety related to cooking pork to higher temperatures, and more consumers were interested in selecting cuts of pork that appeared less well-done due to its perceived juiciness and flavor after participating in the sensory panel.

Tables

Table 3.1 Demographic summary of participating consumers (n = 132) evaluating the effects of cooking method and degree of doneness of boneless pork chops

Characteristic	Response	Percentage of consumers
Age		
	18-25 years old	18.18
	26-35 years old	24.24
	36-55 years old	29.55
	56-75 years old	27.27
	76 years old or older	0.76
Ethnic origin		
	Asian/ Pacific Islander	22.73
	Hispanic or Latino	1.52
	Other	2.27
	White	73.48
Gender	Female	54.55
	Male	45.45
Education level	Completed an advanced or graduate degree	43.18
	Some graduate school	16.67
	Completed an undergraduate degree	13.64
	Some college	21.97
	High school diploma	4.55

Table 3.2 Population summary statistics of pork quality measurements of loins used to provide chops for sensory evaluation

Variable	Number	Mean	Minimum	Maximum	SD	CV
Subjective evaluations[1]						
Visual color	12	3.58	2.5	4.5	0.60	16.65
Visual marbling	12	2.58	1.5	3.5	0.60	23.10
Subjective firmness	12	2.67	2.0	3.0	0.49	18.46
Instrumental color[2]						
Lightness, L*	12	48.89	43.90	52.54	2.98	6.10
Redness, a*	12	5.85	4.38	8.10	1.29	22.04
Yellowness, b*	12	5.33	2.80	7.01	1.23	23.12
Ultimate pH	12	5.70	5.50	6.08	0.21	3.61

[1]NPPC color using the 1999 standards, half point scale where 1 = visually palest color and 6 = visually darkest color

[1]NPPC marbling using the 1999 standards where 1 = visually the least marbling and 6 = visually the most marbling

[1]NPPC firmness using the 1991 standard where 1 = softest and 6 = firmest

[2]L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color).

Table 3.3 Effects of cooking method and degree of doneness (DOD) on instrumental color of cooked pork chops

	Cooking method			Degree of doneness			*P*-value		
	Sous-vide	Grill	SEM	63°C	71°C	SEM	Cooking method	DOD	Cooking method x DOD
Observations, n	24	24		24	24				
Lightness, L*[1]	77.58	77.52	0.29	77.70	77.41	0.29	0.89	0.48	0.54
Redness, a*[1]	4.13	3.79	0.09	4.10	3.82	0.09	0.03	0.01	0.88
Yellowness, b*[1]	9.07	9.40	0.08	9.08	9.39	0.08	0.01	0.01	0.09

[1]L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color).

Table 3.4 Effects of cooking method and degree of doneness (DOD) on consumer sensory traits of pork chops[1,2]

	Sous-vide		Grill			*P*-value		
	63°C	71°C	63°C	71°C	SEM	Cooking method	DOD	Cooking method x DOD
Consumer tenderness								
Not tender	1.39^{c}	15.95^{ab}	10.00^{b}	22.03^{a}	4.26	< 0.01	< 0.0001	0.05
Neutral	15.91^{b}	50.00^{a}	51.52^{a}	54.55^{a}	4.35	< 0.0001	< 0.0001	< 0.001
Tender	82.82^{a}	33.07^{bc}	37.66^{b}	22.42^{c}	4.68	< 0.0001	< 0.0001	< 0.001
Consumer juiciness								
Not juicy	1.47^{c}	34.77^{a}	14.89^{b}	27.85^{a}	4.70	0.01	< 0.0001	< 0.01
Neutral	42.52	53.94	50.89	51.65	4.55	0.49	0.17	0.23
Juicy	55.83^{a}	10.87^{d}	33.47^{b}	19.80^{c}	4.90	0.62	< 0.0001	< 0.001
Consumer flavor								
Not flavorful	16.00	26.05	16.77	18.31	4.27	0.38	0.12	0.26
Neutral	45.21	51.30	51.30	54.34	4.58	0.30	0.30	0.73
Flavorful	38.15	22.10	31.23	26.65	4.81	0.88	0.01	0.16
Overall acceptability								
Not acceptable	2.22^{c}	22.75^{a}	12.01^{b}	21.21^{a}	4.14	0.02	< 0.0001	0.01
Neutral	37.15	50.06	48.55	49.30	4.50	0.22	0.12	0.16
Acceptable	60.34^{a}	26.35^{c}	38.60^{b}	28.63^{bc}	4.87	0.04	< 0.0001	0.01

[a,b] Least square means within a row among main effects lacking a common superscript differ (P <0.05)

[1]Values reported are a percentage of responses for each of the interaction means

[2]Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were consider neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable.

Table 3.5 Frequency and percentage of consumers response to pre-survey questions (n=133)

	Frequency	Percentage
How many times do you eat pork each month?		
More than once a week	54	40.6
2-3 times a month	39	29.3
Once a week	31	23.3
Once a month	6	4.5
Less than once a month	3	2.3
How many times do you cook pork each month?		
More than once a week	40	30.1
2-3 times a month	38	28.6
Once a week	26	19.5
Once a month	17	12.8
Less than once a month	12	9.0
Which of the following ways do you use to cook pork?		
Stove top	107	80.5
Oven	91	68.4
Grill	89	66.9
Slow Cooker	73	54.9
Deep Fryer	11	8.3
Air Fryer	9	6.8
Sous-vide	8	6.0
Other	4	3.0
How do you determine when the pork is done and ready to consume?		
Look at the color of the meat	90	67.7
Use a meat thermometer	67	50.4
Cook for a specific amount of time	44	33.1
Cook until juice runs clear	41	30.8
Other	9	6.8
I do not check to see if it is done	4	3.0

Table 3.6 Frequency and percentage of consumers response to pre-survey and post-survey questions

	Pre-survey		Post-survey	
	Frequency	Percentage	Frequency	Percentage
After looking at the photos, which of the following degree of doneness do you prefer?	n=133		n=133	
Medium	71	53.4	58	43.6
Medium Well	26	19.5	16	12.0
Medium Rare	22	16.5	50	37.6
Well Done	21	15.8	9	6.8
Rare	0	0.0	1	0.8
What is the main reason for why you chose the degree of doneness photo?	n=133		n=133	
Juiciest	46	34.6	60	45.1
Safest to consume	45	33.8	16	12.0
Best texture	30	22.6	32	24.1
Best flavor	29	21.8	34	25.6
Other	7	5.3	2	1.5

Table 3.7 Comparison of pre-survey and post-survey questions regarding degree of doneness preference and safe temperature to consume pork[1]

Survey Questions	Pre-survey		Post-survey	
	mean	SD	mean	SD
Which of the following would you prefer to eat?	3.27	0.9	2.84	0.87
At what temperature (°F) do you think for is safe to consume?	154.43	13.8	144.84	6.3

[1]Degree of doneness definitions were given numerical numbers: 1=Rare; 2=Medium Rare; 3=Medium; 4=Medium Well; 5=Well Done

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